

THE RELATIONSHIP BETWEEN CIRRUS MOVEMENTS FROM EASTERLY POINTS, AND THE OCCURRENCE OF SEVERE DROUTHS.

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SYNOPSIS.

During severe drouths in summer, and preceding them, the cirriform clouds show a persistent though very sluggish movement from easterly points. This drift rarely is interrupted by the local thundershowers that occasionally occur, but ceases just before, or coincidently with, the general rains that break the drouth. During the period of drouth and cirriform cloud movements from easterly points, the cirri generally are few in amount and thin in structure; and they seem to evaporate and disappear quickly.

The phenomenon appears to be associated with a certain type of high pressure, known as the Hudson Bay anticyclone, which moves southerly in series, and, after the apex is over the Lake region or Ohio Valley covers the eastern half of the United States. These anticyclones appear to be of exceptionally great vertical extent.

INTRODUCTION.

The more or less severe summer drouth that periodically visits our middle western agricultural States, and which, in fact, has been quite a frequent visitor to Missouri during the present decade, is one of the most interesting and important phenomenon of our western North American climatology. A satisfactory explanation as to the cause or causes would, of course, possess great economic significance. As is quite obvious the cause or causes are not wholly local, the solution of the physical process that precede and are associated with severe drouths must probably await the application of world-wide meteorology and, perhaps, a larger understanding of the relationships existing between the troposphere and stratosphere. It seems to be a subject worthy of the best efforts of our advanced students of meteorology.

The scientific study of the upper-air currents, however, is not possible to the average observer, because of the lack of proper instruments for determining quantitative values of the several factors involved. In presenting this paper, which deals with upper-air studies, no attempt will be made to treat the subject exhaustively, because, though it embodies many careful eye observations, the data of all quantitative values are lacking. For instance, eye observations of the structure of the clouds give us but a vague idea of the temperature of the current in which they float and no certain value as to height or rate of movement, but, on the other hand, the careful observer can determine their direction of movement with considerable exactness.

During the severe drouth of the summer of 1911, in Missouri, I was impressed by a persistent though extremely slow movement of thin cirriform clouds from the northeast, east, and southeast, and points between. With such movements from abnormal directions, heretofore considered, beginning before and persisting generally throughout the period of drouth, a keen interest was aroused that caused a very careful scrutiny of all cirriform clouds through the succeeding years. On the whole, severe and widespread drouths are not common in Missouri, and, except the remarkable series of the present decade, do not occur more than once in 10 years. So well was this understood that it was a common saying, prior to 1911, especially among the agricultural class, that two successive summer severe drouths were an unheard-of occurrence in Missouri. Closely following the drouth of 1911 came the drouths of 1913 and 1914,

and following the wet and cool summer of 1915, came the drouths of 1916, 1917, and 1918. Rather a serious application from the standpoint of the agriculturist, but a rare opportunity for the meteorologist for the compilation of cloud statistics during drouths has been afforded, and with the recurrence of the abnormal drift of cirrus clouds from easterly points with each drouth, there seems to be some definite connection between these two abnormal conditions.

It might be said at the outset that the entries of cirri in our station records of past years do not well substantiate the conclusions of this paper, and it is not likely that those of other stations will do so. In the first place, the cirriform clouds of drouth times generally are thin and a few in amount, and might be omitted altogether by the casual observer. At such times as they are present in sufficient amount to attract notice their rate of movement is so sluggish, especially when moving from some easterly point, that the 20-minute period usually given to an observation is much too limited, and hence there is a strong tendency on the part of the observer to enter no direction or to assume them from some westerly point, since that is considered their normal direction. Whenever cirri are observed to be moving unusually slowly it is very probable that they are from some direction other than westerly, though it is true they do occasionally move exceedingly slowly from western points during periods of drouth. It is doubted whether cirri ever remain absolutely stationary, though at times the lack of structure prevents the observer from determining their direction to a certainty. Frequent and careful observations ought to be made of cirriform clouds all the year round, but particularly so in spring and summer, and entries verified whenever possible by the official in charge or a competent assistant to the end that what follows may be, if the relations of cause and effect can be traced, put to actual practice as soon as possible, because, as already mentioned, the possibilities of forecasts of severe and prolonged drouths have great economic value.

DISCUSSION OF TABLES.

Table 1 shows the direction and number of times cirriform clouds were observed at the U. S. Weather Bureau, University of Missouri, Columbia, Mo., during 24 years, 1895 to 1918, inclusive. The observations at this station represent days. As only one observation a day was taken (save beginning with the spring and summer of 1911 and up to 1918) special observations of cirriform clouds were made by the writer; but only one entry for any one direction for one day was made. That is, if cirri were observed five or six times during the day and each observation showed that they were moving from the same direction, only one entry was made for that day; if the direction changed, then each direction was recorded. The prevailing direction at Columbia in winter is from the west, or more probable if a nephoscope had been used, west-northwest. Cirri at this station moving from any point save a westerly one in winter are a rare occurrence indeed. Out of 380 observations only

15 show a movement from other points, viz, south 2, north 8, northeast 1, east 2, and southeast 2. The two times cirri were observed coming from the easterly points were drought years.

In spring the prevailing directions is from the west, or west-southwest. Of a total of 531 observations, all but 49 show cirri from some westerly point. Of the 49 from other points, 37 were from easterly directions, 23 occurring in drought years. The shift to easterly directions becomes more frequent in May. In Table 1 the side marginal notes or remarks on the weather conditions refer to State-wide conditions. It may be noticed that during heavy or normal precipitation cirri travel steadily from some westerly point, generally from southwest or west. There is but one exception in this record, i. e., May, 1909; but the August following was the driest of its name in 50 years.

In summer the prevailing direction seems to be from west or west-southwest. Of the total 762 observations all but 191 were from westerly points. Of the 191 from other points, 143 were from easterly directions, and all but four occurred during drought years. Two of those four preceded the great drought of 1901.

In autumn the prevailing direction is from the west during September and October, and from west-northwest in November. As during the winter months, one rarely observes the cirriform clouds from any other directions save westerly in autumn. Out of 430 observations all but 17 were from westerly points; of these 17, 3 were from the northeast and 3 from east or southeast.

Table 2 consists of special cloud observations, made at Columbia, Mo., during the severe drought of the summer of 1911. This shows that the higher clouds (probably above 4,500 meters) very nearly boxed the compass for the period entered; and the breaking up of the drought followed the shift of cirri from easterly to westerly directions, or to what usually is considered their normal track. There was no nephoscope at hand, but the observations were taken by the writer, who has been a field meteorologist for more than 30 years, and each observation was verified by his first assistant. From this table we find that from about June 21 to July 6, 1911, a deep easterly wind, probably 5,000 meters deep, was persistent. The surface winds during this time were variable but mostly from points east of south. After July 8, a deep westerly wind prevailed. The surface winds were variable, becoming steady northeast on the 13th, 14th, and 15th. The drought, which had been wide-spread and well-nigh disastrous, was modified by good rains on the 9th and by frequent showers thereafter. The upper current apparently shifted from easterly to westerly on the 8th or 9th. The observations continued daily, but there were no upper clouds observed on the missing dates in the table. It is possible that the upper current changed its course on some date when there was no cirri. In a case like this pilot balloons and theodolites would be invaluable. However, it has been noticed that it requires a day or two for cirri to take up their normal movement in the west after traveling from easterly points. The movement from the east always is slow; after resuming the movement from the west, the traveling at first is slow—a movement that sometimes takes many long minutes to define.

Table 3 gives the direction and number of times cirriform clouds were observed during the time stated at Drexel, Nebr., Aerological Station. This record represents observations and not days, and there were many observations, as a rule, during a day. At this station very few instances are found in which cirri travel out of

their normal westerly routes. Out of 2,270 observations all but 56 were observed as coming from westerly points; out of the 56, 17 were from easterly directions; and the phenomenon, similar to the record of Columbia, Mo., appears to be associated with spring and summer seasons, and drought years. When coming from easterly points the winds are deep, as indicated by intermediate cloud movements, similar to Table 2, Columbia. At Drexel a deep northeast wind occurred on March 26, and June 29, 1916; a southeast wind on May 20, 1917, and an east wind on March 22, 1918. Our Columbia record shows that in midsummer the prevailing direction of cirrus clouds is from the west or south of west. The record at Drexel shows that the direction backs to northwest in July and August, at least for these two months for the three years indicated.

Table 4 shows that at times the upper part of the troposphere (the cirrus region) is in a variable state over a great area at the same time.

Drought conditions prevailed in Missouri generally during June, July, and the first seven days of August, 1918. From about July 20 to August 7 the lack of moisture and accompanying heat were well-nigh disastrous to growing crops; but the drought was broken by good rains on August 8 and 9, and frequently thereafter. It is of interest to note that the "prevailing westerlies," as indicated to us by the upper cloud movement, again became practically normal just before the breaking of the drought and continued so, with but slight interruption, during the remainder of the month.

That there appears to be some connection between the reversing of the upper current's usual eastward movement and drought is further brought out by the following résumé:

Year.	Cirriform clouds first observed from easterly points.	Last observed.	Subsequent weather conditions.
1911	In March.....	July 7	Drouth, May to mid-July.
1912	None observed from easterly.....	Seasonable summer.
1913	In May.....	Aug 8	Drouth, May to September.
1914	In May.....	July 31	Drouth, May to mid-August.
1915	None observed from easterly.....	Wet season.
1916	In June.....	Aug. 1	Drouth, last week June to mid-August.
1917	In June.....	July 4	Drouth, July, confined mostly to central Missouri.
1918	In April.....	Aug. 5	Drouth, last week May to first week August.
1919	In May.....	Rainfall June 4-July 8, 52 per cent of average for this period.

During 1919, cirrus clouds were first observed moving from the east on May 29, and since this phenomenon has been observed at this station only during and just prior to periods of drouth, it was believed there would be diminishing rainfall during the summer. For five weeks, from June 4 to July 8 (the date this paper was practically finished) the total rainfall was 2.70 inches, or about 52 per cent of the normal amount, as shown by the following short table, for the State as a whole:

Date.	Rainfall.	Normal.	Departure.
June 4 to 10.....	0.76	1.00	-0.24
June 11 to 17.....	0.61	0.81	-0.20
June 18 to 23.....	0.49	1.01	-0.52
June 24 to July.....	0.43	1.22	-0.79
July 2 to July 8.....	0.41	1.13	-0.72
Total for 5 weeks.....	2.70	5.17	-2.47

All investigators in their studies of the upper clouds have shown that for cirriform clouds to move from an easterly point is an unusual phenomenon. Espy, in

his studies of the easterly motions of the upper current, said he had found that the *true* cirrus clouds averaged scarcely one a year from an easterly direction, and when

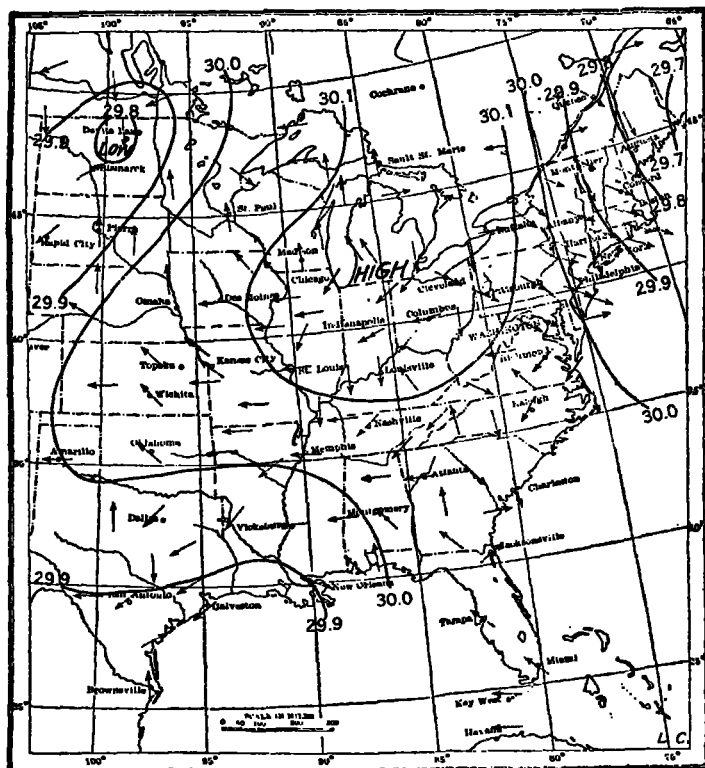


FIG. 1.—Typical pressure distribution accompanying movement of cirrus clouds from the east. (Morning weather map, June 21, 1911.)

they did come from an easterly direction it was only when there was a cyclone of uncommon violence in the east. When assigned to the Gulf Coast, years ago, I observed cirrus clouds from the east when there was a hurricane in the Gulf. Except for this I never have known cirrus clouds to come from the east because of a cyclone to the eastward. In my studies of this phe-

nomenon, I have noticed that cyclones seem to affect the direction of cirrus clouds only a point or two, studied from the latitude of Columbia, Mo. Ferrel¹ writing of the movement of the upper current, states that cyclonic component was merely sufficient, for the most part, to cause deviations of a few points from the usual eastward course, and rarely sufficient to reverse entirely that strong current and give rise to a motion from the east. This also is in accordance with Ley's studies of the motion of the upper current.

I have observed at the Columbia station that whenever the upper clouds are seen to be moving from some easterly point the phenomenon apparently is associated with a certain well-marked pressure distribution, that is, the pressure is high, when averages are considered, over the territory east of the Mississippi and relatively low west of it. (See fig. 1.) While it does appear that the movements of the cirriform clouds are to some extent dominated by a certain type, Hudson Bay summer anticyclone, all summer anticyclones do not have this power. The winter anticyclones, although apparently of great magnitude and influence, do not change the direction, so far as my observations go, of the cirrus clouds save one or two points. It may be, as observed by Ferrel, the easterly motion of the upper current is too strong in winter to be reversed by either the anticyclone or cyclone, although of great depth and power.

Summer, as a rule, is the season when the Hudson Bay anticyclones are at their minimum.² But when this rule is broken, when anticyclones come out of the north in June in series, then widespread and more or less severe drouth is probable; and the early effects of the prevalence of the Hudson Bay summer anticyclonic series will be, firstly, a more or less stagnant condition, in a comparative sense, of the upper easterly-flowing current, and secondly, the *cirriform clouds, generally thin in structure, slow of movement, will be coming from the east.* The phenomena may first be noticed as early as March and with increased frequency in May.

¹ A popular treatise on the winds, New York, 1889, p. 308.

² E. H. Bowie and R. H. Weightman. Types of anticyclones of the United States and their average movements. MONTHLY WEATHER REVIEW, SUPPL. 4, 1917.

TABLE 1.

Direction of Cirrus or Cirro-stratus clouds at Weather Bureau station, University of Missouri, Columbia, Mo., in winter. The prevailing direction seems to be from the west, or probably more nearly west-northwest.

[This station is in lat. 38° 57'; long. 92° 20'; elevation, 238 meters.]

Direction from, in winter.	December.								January.								February.								Remarks.
	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	
1894-95.....	0	2	6	3	0	0	0	0	0	2	1	0	0	0	0	0	3	4	6	0	0	0	0	0	
1895-96.....	0	6	7	2	0	0	0	0	0	3	4	5	0	0	0	0	0	4	5	6	0	0	0	0	
1896-97.....	0	2	6	2	0	0	0	0	0	3	2	5	0	0	0	0	0	2	3	3	0	0	0	0	
1897-98.....	0	1	2	3	1	0	0	0	0	0	6	1	0	0	0	0	0	3	2	4	0	0	0	0	
1898-99.....	0	1	3	2	0	0	0	0	0	2	2	0	0	0	0	0	0	2	3	1	0	0	0	0	
1899-1900.....	0	0	2	6	0	0	0	0	0	2	3	6	0	0	0	0	0	2	2	4	0	0	0	0	
1900-1901.....	0	3	0	1	0	0	0	0	0	0	3	1	0	0	0	0	0	0	1	2	0	0	0	0	
1901-2.....	0	1	4	3	1	0	1	0	0	1	2	6	2	0	0	0	0	0	5	8	0	0	0	0	
1902-3.....	0	2	0	3	0	0	0	0	0	4	1	4	0	0	0	0	0	1	5	0	0	0	0	0	
1903-4.....	0	0	4	2	0	0	0	0	0	1	5	1	0	0	0	0	0	1	4	1	0	0	0	0	
1904-5.....	0	1	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
1905-6.....	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	
1906-7.....	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1907-8.....	0	0	1	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	1	1	0	0	0	0	
1908-9.....	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	0	1	2	0	0	0	0	1	
1909-10.....	0	1	1	2	0	0	0	0	0	3	1	2	0	0	0	0	0	0	2	0	0	0	0	0	
1910-11.....	0	1	0	3	0	0	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	
1911-12.....	0	2	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	
1912-13.....	0	5	4	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	
1913-14.....	0	1	1	0	0	0	1	0	0	2	6	1	1	0	0	0	0	1	5	0	0	1	0	0	
1914-15.....	0	0	2	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	
1915-16.....	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	
1916-17.....	0	0	2	1	0	0	0	0	0	3	3	1	0	0	0	0	0	0	2	3	0	0	0	0	
1917-18.....	0	0	3	2	0	0	0	0	0	1	2	2	1	0	0	0	0	1	4	2	0	0	0	0	
Total.....	1	31	54	37	4	0	2	0	0	30	53	37	4	0	0	1	1	28	49	44	0	1	0	1	

Direction from, in spring.	March.								April.								May.								Remarks. (State-wide conditions.)
	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	
1895.....	0	2	3	6	0	0	0	0	0	1	5	3	0	0	0	0	1	5	7	5	0	0	0	0	Nearly normal spring.
1896.....	0	4	6	4	0	0	0	0	1	7	7	1	0	0	0	0	1	4	4	2	0	0	0	0	Wet May, otherwise above normal.
1897.....	0	5	1	2	0	0	0	0	0	1	0	1	0	0	0	0	1	2	4	3	0	0	0	1	Wet March and April, dry May.
1898.....	0	3	1	2	0	0	0	0	0	1	2	1	0	0	0	0	0	1	4	0	0	0	0	0	Normal April, very wet March and May.
1899.....	0	1	5	1	0	0	0	0	0	1	2	4	0	0	0	0	0	3	8	0	0	0	0	0	Wet May, otherwise nearly normal.
1900.....	0	1	1	5	0	0	0	0	0	5	1	2	1	0	0	0	0	2	3	2	1	0	0	0	Below normal.
1901.....	0	1	3	4	0	0	0	0	0	1	2	3	0	1	0	0	0	2	4	1	1	0	0	0	Exceptionally dry May.
1902.....	0	2	7	4	0	0	0	0	0	2	8	4	0	0	0	0	2	4	3	3	0	0	0	0	Rather wet May.
1903.....	0	5	0	1	0	0	0	0	0	5	2	3	1	0	0	0	2	10	1	0	0	0	0	0	Excessively wet May.
1904.....	0	5	2	1	0	0	0	0	0	4	3	1	0	0	0	0	0	3	3	0	0	0	0	0	A wet spring.
1905.....	0	3	4	0	0	0	0	0	0	1	2	0	0	0	0	0	0	1	7	0	0	0	0	0	About normal.
1906.....	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	4	0	0	0	0	0	Slightly below normal.
1907.....	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2	1	0	0	0	0	May wetter than normal.
1908.....	0	1	1	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	1	0	0	0	0	0	Wet April and May.
1909.....	0	2	2	0	0	0	0	0	0	2	1	1	0	0	0	0	1	2	0	0	0	0	0	2	April and May above normal.
1910.....	0	0	1	3	0	0	0	0	0	1	1	1	0	0	0	0	0	1	4	0	0	0	0	0	A dry March, wet May.
1911.....	0	0	1	0	0	2	0	0	0	0	5	0	1	1	0	0	0	1	8	2	0	0	3	1	Dry March, wide-spread drought May.
1912.....	0	0	0	0	0	0	0	0	0	1	2	2	0	0	0	0	0	7	8	2	0	0	0	0	Rather wet March and April.
1913.....	0	5	2	2	0	0	0	0	0	3	4	2	0	0	0	0	1	4	5	2	1	1	2	2	Wet March, normal April, dry May.
1914.....	0	1	4	1	0	0	0	0	1	1	5	1	0	0	0	0	0	2	9	1	0	1	3	2	Widespread drought in May.
1915.....	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	3	3	0	0	0	0	0	Exceptionally wet May.
1916.....	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	May wetter than normal.
1917.....	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5	0	0	0	0	0	

Direction from, in summer.	June.								July.								August.								Remarks. (State-wide conditions.)
	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	
1895.....	1	3	6	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	Wet summer.
1896.....	0	1	3	3	2	0	0	0	0	0	1	2	3	0	0	0	0	0	7	2	2	0	0	0	Do.
1897.....	1	3	3	4	0	0	0	0	0	0	3	2	2	0	0	0	0	0	2	3	1	0	0	0	August drier than normal.
1898.....	1	5	1	2	0	0	0	0	1	1	3	3	0	0	0	0	1	0	2	5	1	0	0	0	About normal summer.
1899.....	0	7	2	4	0	0	0	0	0	2	5	2	0	0	0	0	0	5	1	0	0	0	0	0	About normal.
1900.....	1	6	2	2	1	1	0	0	0	7	2	2	0	0	0	0	0	8	2	1	0	0	0	0	Normal.
1901.....	3	5	5	1	0	0	4	0	0	4	2	2	1	1	3	3	0	1	1	4	1	1	2	0	Severe drought.
1902.....	0	5	7	3	0	0	0	0	0	10	2	2	0	0	0	0	0	2	5	6	0	0	0	0	Nearly normal summer.
1903.....	0	3	5	5	0	0	0	0	0	5	3	5	0	0	0	0	0	2	3	5	0	0	0	0	Rather wet.
1904.....	0	8	5	5	0	0	0	0	0	10	3	5	0	0	0	0	0	2	3	5	0	0	0	0	Do.
1905.....	0	3	6	0	0	0	0	0	0	5	3	5	0	0	0	0	0	4	6	0	0	0	0	0	Do.
1906.....	0	5	3	0	0	0	0	0	0	1	8	0	0	0	0	0	0	1	5	0	0	0	0	0	About normal.
1907.....	0	3	3	0	0	0	0	0	0	1	8	0	0	0	0	0	0	2	2	0	0	0	0	0	Wetter than normal.
1908.....	0	0	0	0	1	0	0	0	0	1	4	0	1	0	0	0	0	0	2	0	1	0	0	0	July drier than normal.
1909.....	0	0	1	0	0	1	1	0	0	4	1	1	0	0	0	0	3	0	2	1	0	0	1	0	August drier on record.
1910.....	0	3	3	1	0	0	0	0	0	2	3	2	0	0	0	0	0	0	5	0	0	0	0	0	Above normal.
1911.....	0	2	2	1	0	3	5	3	1	2	3	2	2	0	0	0	0	1	4	2	0	0	0	0	Drought in June-July.
1912.....	0	2	2	2	0	2	0	0	1	3	6	4	2	2	1	0	0	2	4	1	0	0	0	0	Drought in July.
1913.....	1	3	8	1	1	3	5	4	2	1	0	3	4	1	0	6	3	5	3	1	3	5	4	0	Severe drought.
1914.....	1	3	7	1	0	3	4	0	1	0	3	6	3	2	4	0	0	3	6	2	0	0	0	0	Drought June-July.
1915.....	0	3	3	1	0	0	0	0	0	1	0	3	4	0	0	0	0	0	1	0	0	0	0	0	Unusually wet.
1916.....	0	3	3	0	0	1	3	2	0	2	4	0	0	0	0	8	5	3	1	4	1	0	3	5	Drought in July-August.
1917.....	0	4	5	0	1	0	0	0	0	1	3	3	1	0	0	2	0	0	4</						

Direction from, in autumn.	September.								October.								November.								Remarks. (State-wide conditions.)
	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	
1895.....	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	October dry, otherwise normal.
1896.....	0	0	3	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0	1	2	0	0	0	0	Nearly normal autumn.
1897.....	0	0	4	1	1	0	0	0	2	1	1	0	0	0	0	0	0	0	4	3	0	0	0	0	Dry September, extra dry October.
1898.....	0	2	3	2	0	0	0	0	1	1	1	0	0	0	0	0	0	5	3	0	0	0	0	0	Wet September and October.
1899.....	0	0	1	4	0	0	0	0	2	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	About normal.
1900.....	0	4	2	3	0	0	0	0	1	4	3	0	0	0	0	1	0	0	2	3	0	0	0	0	Not unusual.
1901.....	1	1	3	2	0	0	0	0	2	3	1	0	0	0	0	0	0	0	1	5	1	0	0	0	Drier than normal.
1902.....	0	0	4	1	0	0	0	0	1	4	2	0	0	0	0	0	0	2	1	0	0	0	0	0	About normal.
1903.....	0	5	2	2	0	0	0	0	2	2	0	0	0	0	0	0	0	1	2	2	0	0	0	0	Do.
1904.....	0	2	4	1	0	0	0	0	2	2	1	0	0	0	0	0	0	1	0	1	0	0	0	0	October-November drier than normal.
1905.....	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	September exceptionally wet.
1906.....	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	Dry October.
1907.....	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	Dry September.
1908.....	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	Dry September, wet November.
1909.....	0	3	2	1	0	0	0	0	0	3	1	0	0	0	0	0	0	2	3	4	0	0	0	0	Wet November.
1910.....	0	1	4	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	2	3	0	0	0	0	Wet September, dry November.
1911.....	0	2	4	3	0	0	0	0	2	5	2	0	0	0	0	0	0	4	4	3	0	0	0	0	Wet September.
1912.....	0	4	5	2	0	0	0	0	2	6	2	0	0	0	0	0	0	2	7	7	3	0	0	0	Nearly normal.
1913.....	0	7	4	2	1	0	0	0	3	7	2	0	0	0	0	0	0	3	3	2	0	0	0	0	September and October wetter than normal.
1914.....	0	1	3	1	0	0	0	0	1	6	3	0	0	0	0	0	0	2	6	2	0	0	0	0	Wet September, dry November.
1915.....	0	3	6	2	0	0	0	0	2	7	2	0	0	0	0	0	0	1	4	3	0	0	0	0	Wet September and October.
1916.....	0	2	7	3	0	0	0	0	1	5	2	0	0	0	0	0	0	2	5	3	0	0	0	0	Dry September.
1917.....	0	1	6	2	0	2	1	0	2	8	3	1	0	0	0	0	0	3	5	6	0	0	0	0	Dry November.

TABLE 2.—Special eye-observation of clouds (approximately 5,000 to over 10,000 meters elevation) at the U. S. Weather Bureau, University of Missouri, Columbia, Mo., from June 21 to July 15, 1911, severe drought period, being much modified, however, on and after July 9, beginning with the shift of the cirriform cloud movements from easterly to westerly direction.

Date, 1911.	Kind and amount in tenths.	Direction from and time observed.	Other conditions, sky, etc.
June 21.	Cl. Few to 1	ESE. 7:30 p. m.—8:30 p. m.	Hot. Brassy sky.
June 22.	Cl. Few to 1	ESE. 9:45 a. m.—11 a. m.	Do.
June 22.	Cl. Cu. 2 to 5	SE. 9:45 a. m.—10:15 a. m.	Do.
June 23.	Cl. Few to 1	ESE. 7:45 a. m.—8:20 a. m.	Do.
June 23.	A. Cu. 4 to 6	SE. 9:45 a. m.—11:55 a. m.	∞
June 24.	Cl. St. 1 to 3	ESE. 6:30 p. m.—7 p. m.	∞ [11:35 a. m., SW.
June 25.	Cl. Cu. 1 to 2	ESE. 6 p. m.—6:30 p. m.	Hot. Brassy sky.
June 26.	Cl. St. 2 to 3	SE. 9 a. m.—9:30 a. m.	Hot, dry.
June 26.	Cl. Few	ESE. 11:10 a. m.—11:18 a. m.	[11:35 a. m., SW.
June 29.	Cl. Few	ESE. 10 a. m.—10:20 a. m.	Hot, dry.
July 1.	Cl. Few to 1	ESE. 10 a. m.—10:30 a. m.	Hot. Glaring sky.
July 1.	Cl. Cu. Few to 2	SE. 7 p. m.—7:15 p. m.	
July 6.	Cl. St. 1 to 3	ESE. 7:30 p. m.—8:30 p. m.	Hot and dry.
July 6.	A. Cu. 3 to 6	ENE. 9 p. m.—10:30 p. m.	
July 8.	Cl. St. 1 to 2	SW. 6:30 p. m.—7:30 p. m.	Do.
July 9.	Cl. Cu. 1 to 3	SSW. 10 a. m.—10:30 a. m.	Clear, sultry, a. m. [3:45 p. m.—7 p. m.
July 10.	Cl. Cu. 1 to 3	SSW. 7:40 a. m.—8:10 a. m.	Bluer sky and lower temperature.
July 10.	Cl. 1 to 2	SW. 8:30 a. m.—9 a. m.	
July 10.	Cl. St. 2 to 4	SW. 10:30 a. m.—11 a. m.	
July 10.	Cl. St. 4 to 5	SW. 3:45 p. m.	
July 10.	Cl. 1 to 2	SW. 7 p. m.	
July 11.	Cl. Few to 2	SW. 8 a. m.—9 a. m.	Sultry.
July 11.	A. Cu. 2 to 4	NNW. 9:34 a. m.—11 a. m.	
July 11.	A. St. 4 to 7	WSW. 12:45 p. m.—4 p. m.	0-6°.
July 12.	A. Cu. 2 to 3	W. 4 p. m.	Blue sky. Cumulus.
July 13.	Cl. Cu. 2	WSW. 9:15 a. m.	Do.
July 13.	Cl. Cu. 5	WSW. 9:55 a. m.	
July 14.	Cl. Few to 2	WNW. 7:35 a. m.	Do.
July 14.	Cl. Few to 1	WNW. 12:45 p. m.	Do.
July 15.	Cl. 2 to 3	NW. 8:45 a. m.	[2:16 p. m., W., and 6 p. m., SW.
July 15.	Cl. 2 to 3	NW. 12 noon	

TABLE 3.—Direction of Cirrus and Cirro-stratus clouds at Drexel Aerological Station, Lat. 41° 20' N., Long. 96° 16' W.; elevation above sea level 396 meters; from Oct. 22, 1915, to Aug., 1918.

Direction from. ¹	Winter. ²			Spring. ³			Summer. ⁴			Autumn. ⁵			Totals.
	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	
S.	0	0	1	0	0	0	6	0	4	0	0	3	S. 14
SSW.	1	0	0	0	4	9	10	3	1	3	0	3	SSW. 35
SW.	11	6	1	16	8	11	5	12	34	23	20	28	SW. 173
WSW.	12	54	22	41	30	35	25	13	25	49	12	18	WSW. 336
W.	52	53	81	96	47	60	60	26	17	50	35	30	W. 607
WNW.	67	49	61	65	48	41	31	18	19	29	74	50	WNW. 511
NW.	53	45	36	63	54	17	25	64	42	17	24	38	NW. 478
NNW.	14	0	13	9	9	0	7	9	0	0	3	10	NNW. 74
N.	0	0	15	4	1	0	0	0	0	0	0	5	N. 25
NNE.	0	0	0	0	0	0	0	0	0	0	0	1	NNE. 1
NE.	0	0	0	3	0	0	0	0	0	0	0	1	NE. 4
ENE.	0	0	0	0	0	0	4	0	0	0	0	0	ENE. 4
E.	0	0	0	4	0	0	0	0	0	0	0	0	E. 4
ESE.	0	0	0	0	0	0	0	0	0	0	0	0	ESE. 0
SE.	0	0	0	0	0	1	0	0	0	0	0	0	SE. 1
SSE.	0	0	0	0	0	3	0	0	0	0	0	0	SSE. 3
	WNW	WSW	W	W	NW	W	W	NW	NW	W	WNW	WNW	W. 607

¹ By nephoscope.² Dec., 1915–Feb., 1918.³ Mar., 1916–May, 1918.⁴ 1916–1918.⁵ Oct. 22, 1915, to Nov. 30, 1917.

TABLE 4.—Number of times upper clouds (Cl., Ci.St., or Ci.Cu.) were observed moving from the N., NE., E., etc.

JANUARY AND FEBRUARY, 1918.

MAY AND JUNE, 1918.

Station.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Omaha, Nebr.	0	0	0	0	0	8	32	13
Des Moines, Iowa	2	0	0	0	2	2	9	17
Kansas City, Mo.	7	0	1	1	4	17	39	16
Columbia, Mo.	3	0	0	0	0	6	21	8
Springfield, Ill.	0	0	0	0	0	12	23	11
Wichita, Kans.	5	2	0	0	0	22	42	33
Springfield, Mo.	3	0	1	1	4	9	11	9
Nashville, Tenn.	1	0	0	0	0	16	16	8

Station.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Omaha, Nebr.	0	1	0	0	0	15	66	7
Des Moines, Iowa	2	0	1	0	0	15	26	24
Kansas City, Mo.	5	0	0	0	2	34	42	15
Columbia, Mo.	3	0	1	0	0	15	27	9
Springfield, Ill.	1	0	0	0	4	15	55	14
Wichita, Kans.	1	1	0	0	6	47	45	25
Springfield, Mo.	0	0	0	2	14	23	20	6
Nashville, Tenn.	4	3	1	0	1	11	29	9

MARCH AND APRIL, 1918.

Station.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Omaha, Nebr.	0	0	0	1	1	4	59	18
Des Moines, Iowa	4	6	4	1	6	5	28	16
Kansas City, Mo.	10	2	0	0	9	22	42	14
Columbia, Mo.	1	2	4	1	2	10	13	4
Springfield, Ill.	1	0	3	0	2	12	27	6
Wichita, Kans.	3	3	3	3	5	26	37	34
Springfield, Mo.	3	5	3	2	7	13	17	2
Nashville, Tenn.	8	7	1	0	7	18	15	5